



## Railway Network Design in Denmark

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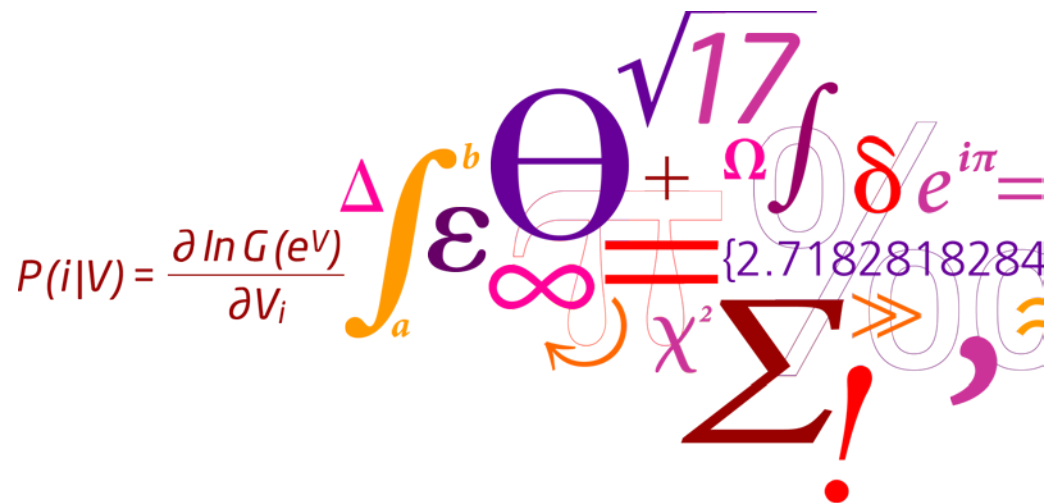
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# Railway Network Design in Denmark

INFORMS Annual Meeting 2014, San Francisco

Dr. Steven Harrod



# Rail Transport in Denmark

- History
- National Transport Model
- Investment Projects
- Example

# A Familiar Scenario

- Network Originates from 1850-1880
- Primarily to Connect Port Cities
- Largely Unchanged Since 1940



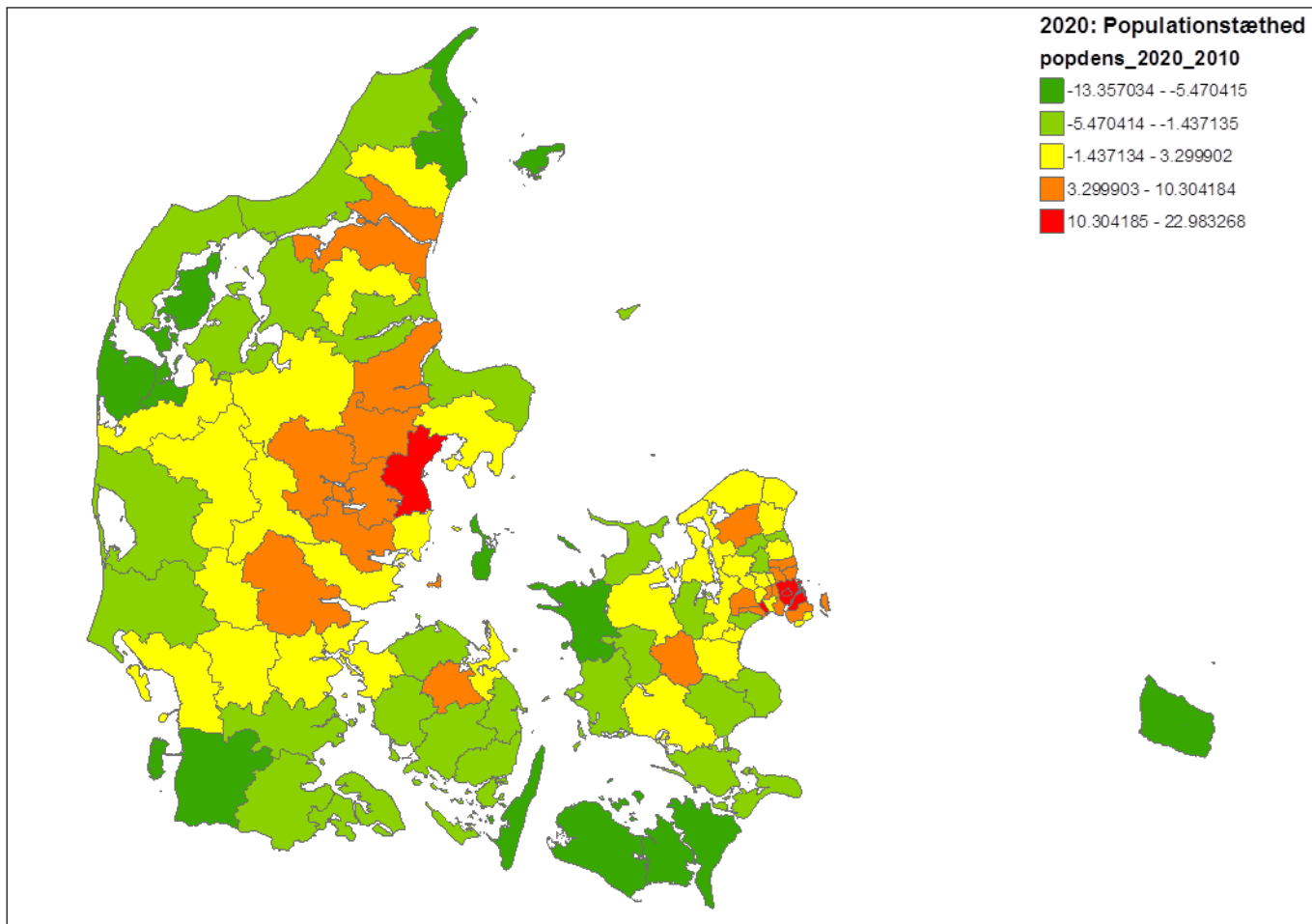
# The Real Denmark



# Many Islands of Denmark

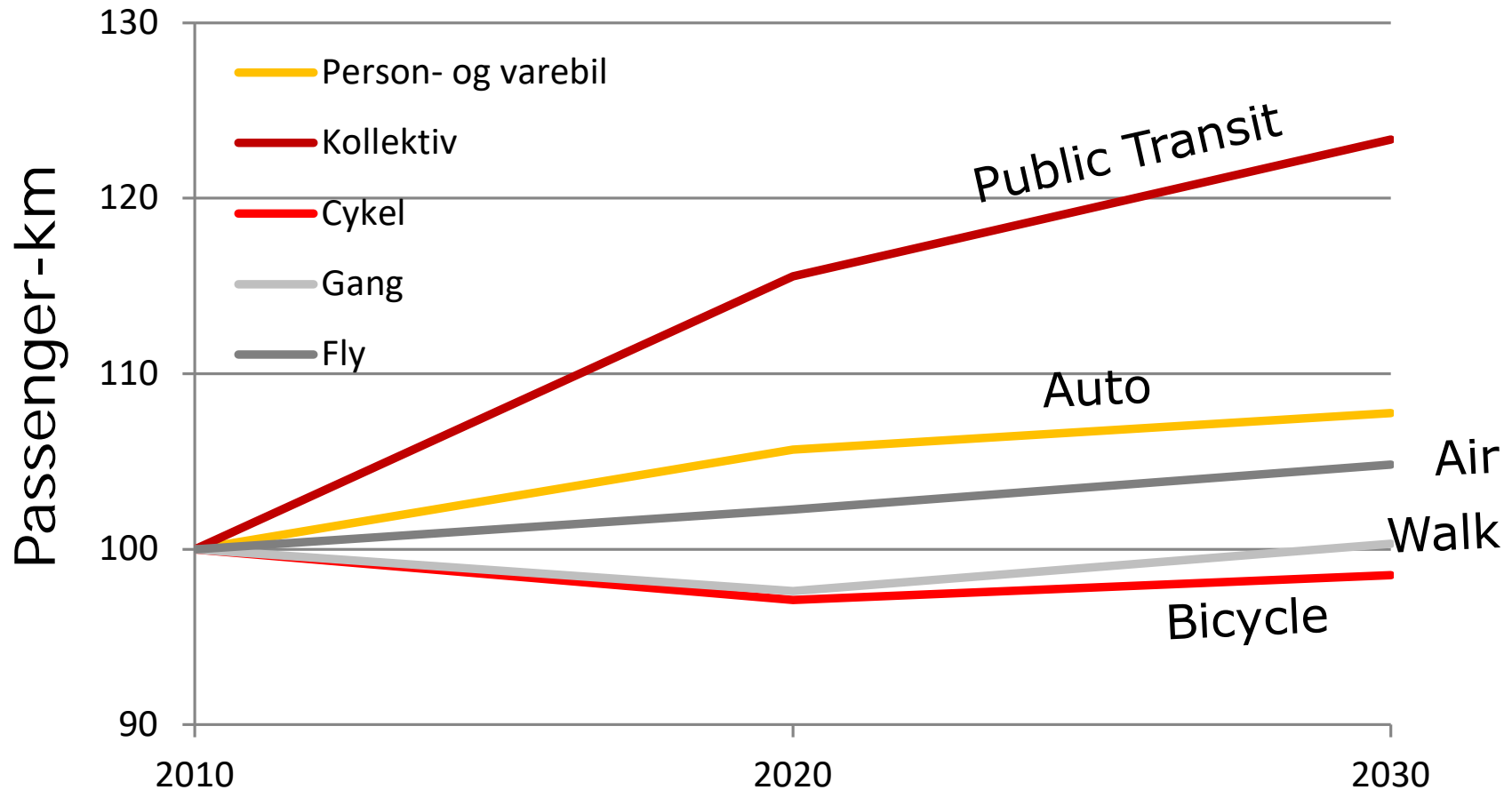


# The Urban Future





# Transport Demand







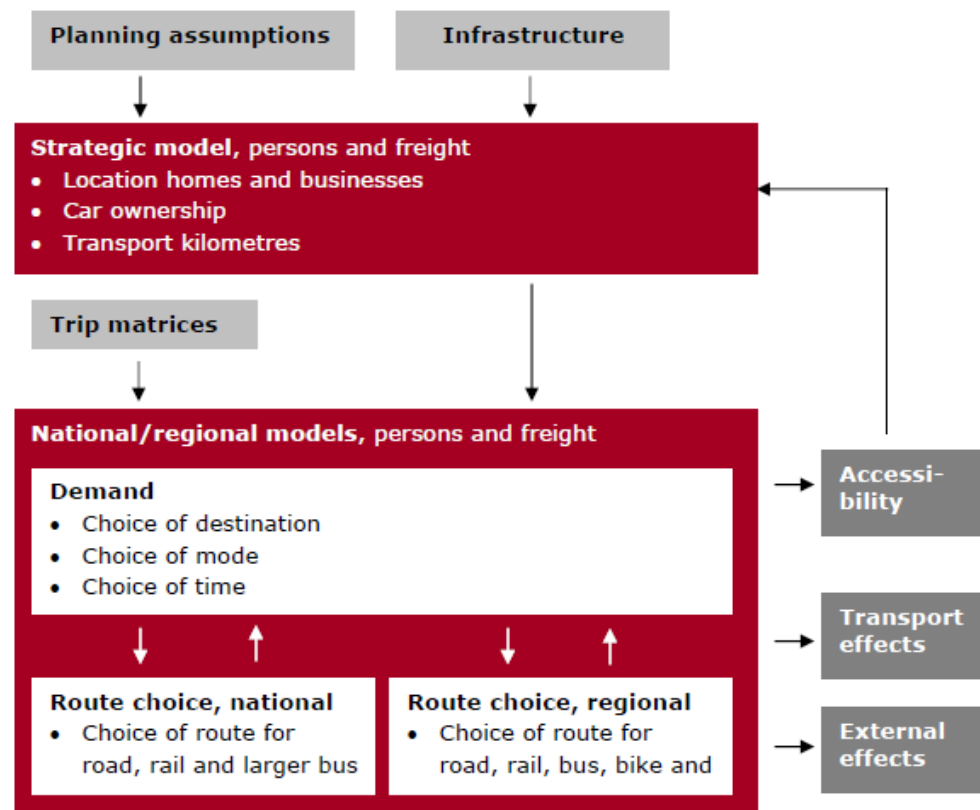
# Political Winds

- 1979 Electrification Plan
- North Sea Oil Boom 1980 > > > >
- 1981, 1994 Electrification Suspended
- 1997 DSB Split
- 1998 "Gode Tog Til Alle"
- The IC4 Debacle
- Togfonden 2013



# The National Transport Model “Landstrafikmodellen”

- Funded by the Danish Government at 60 million kroner (\$10.5 mil.)
- Managed at DTU
- Project Life 2009 to 2020
- INTEGRATED
  - All modes
  - Whole nation
  - Freight and Passenger





# The National Transport Model

## • Strategic level

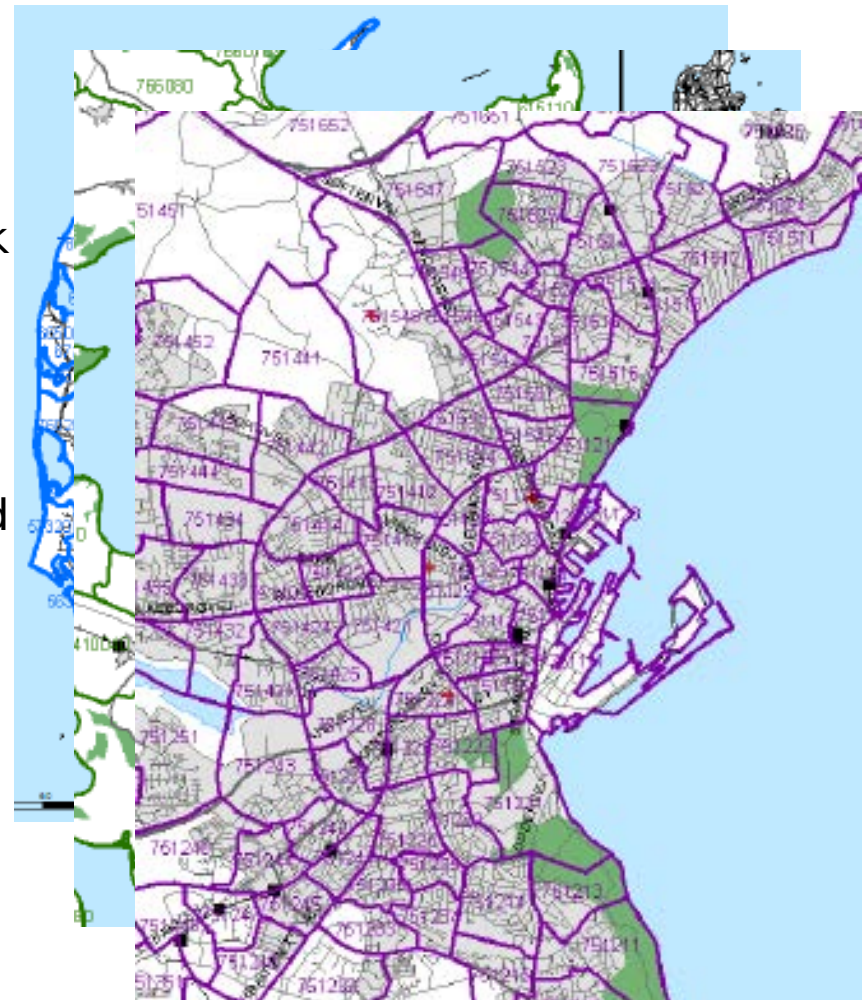
- Screening of large projects
- Road, rail, air, important bus lines
- 176 zones, overall road network

## • National level

- Analysis of national projects
- + Road (driver & passenger), bike and walk
- 907 zones, most important road network

## • Regional level

- Detailed analysis of decided projects and regional projects
- + more bus lines
- 3670 zones and most roads
- Cross roads, traffic lights

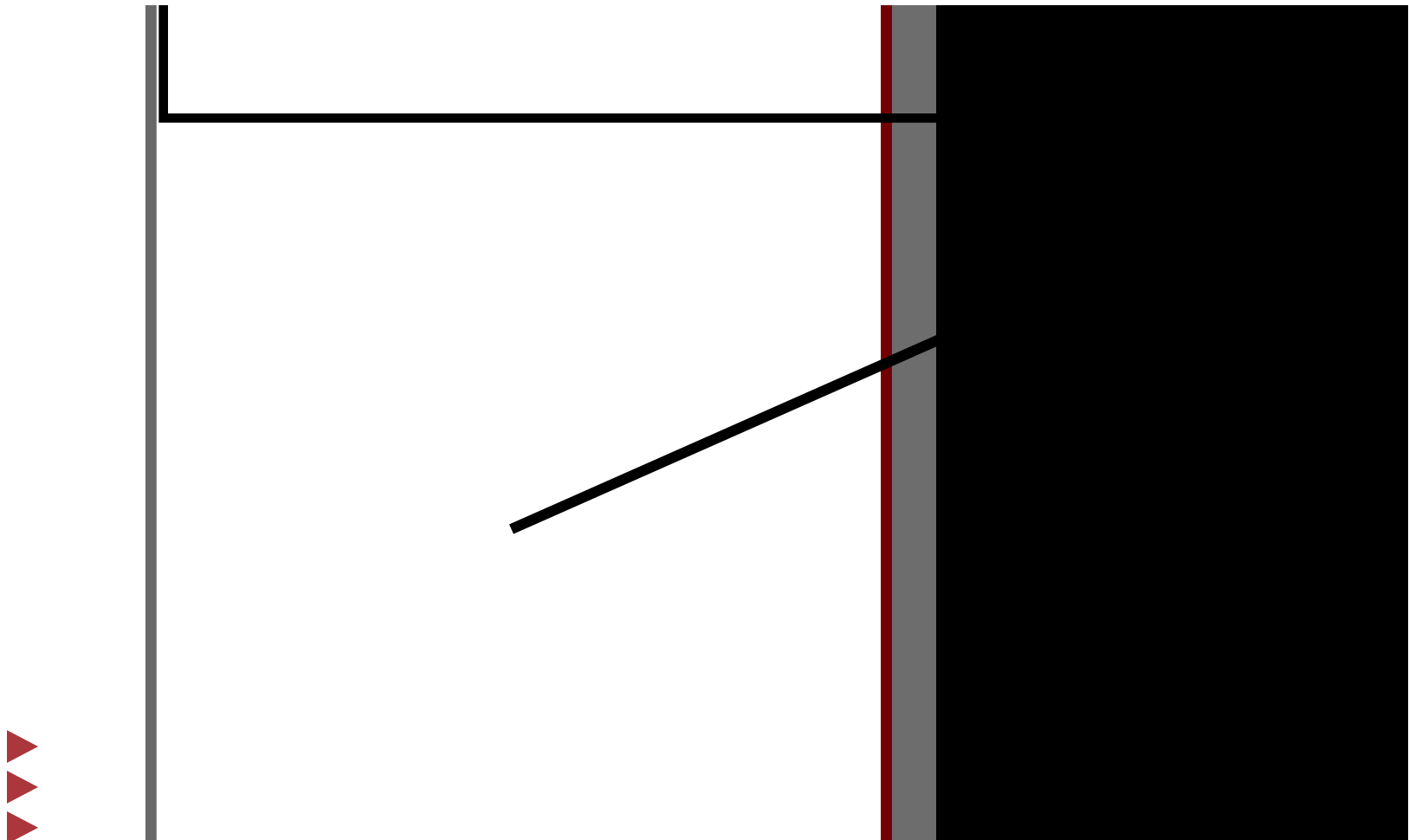


# A Social Laboratory

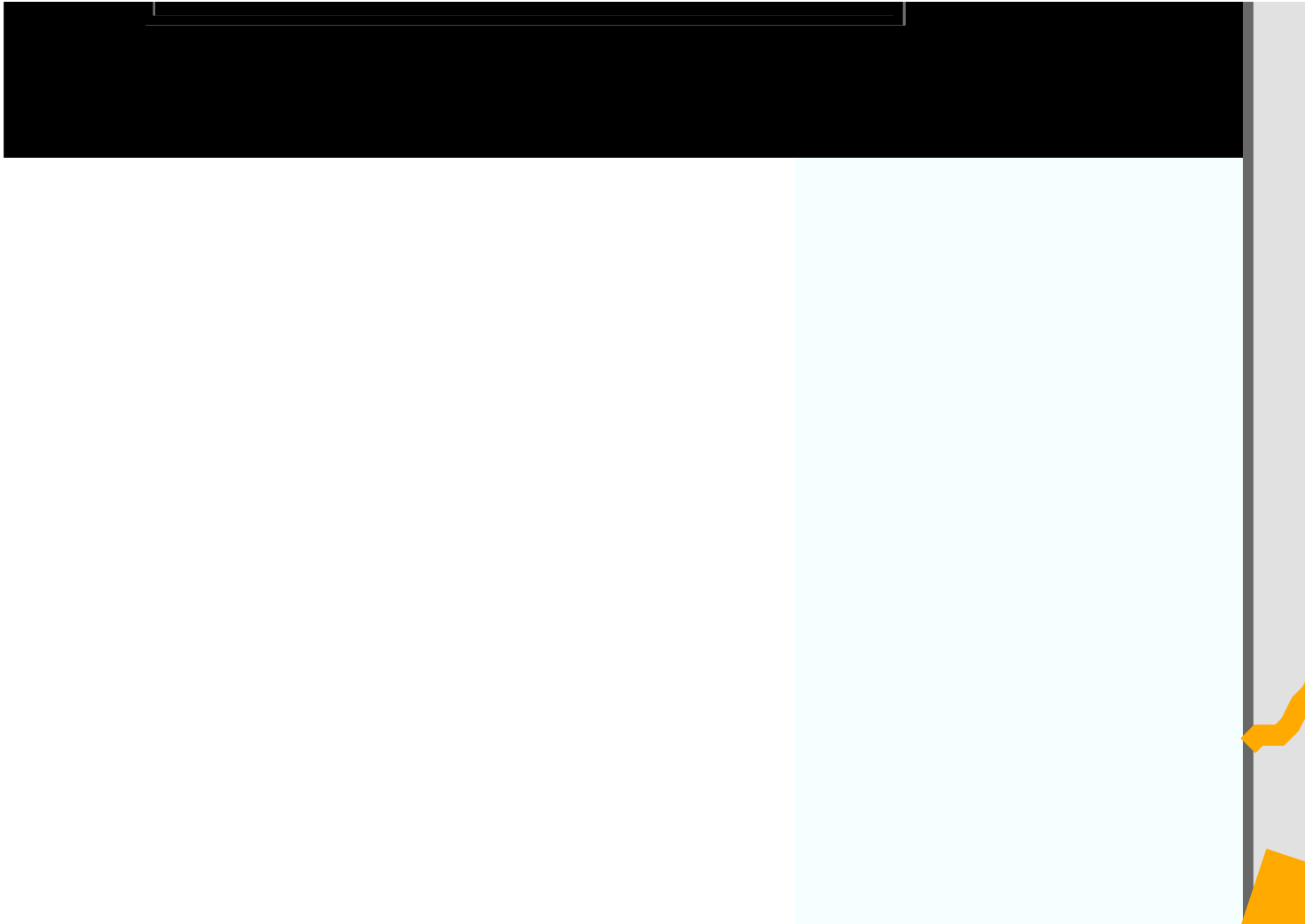
- National Travel Survey
  - Double sample mid 2009 – mid 2011
  - Model based on 87.000 interviews (260.000 single trips)
  - Data collections continuously since 1992
    - Able to identify behaviour and trends
- Rejsekort
- National Citizen Register



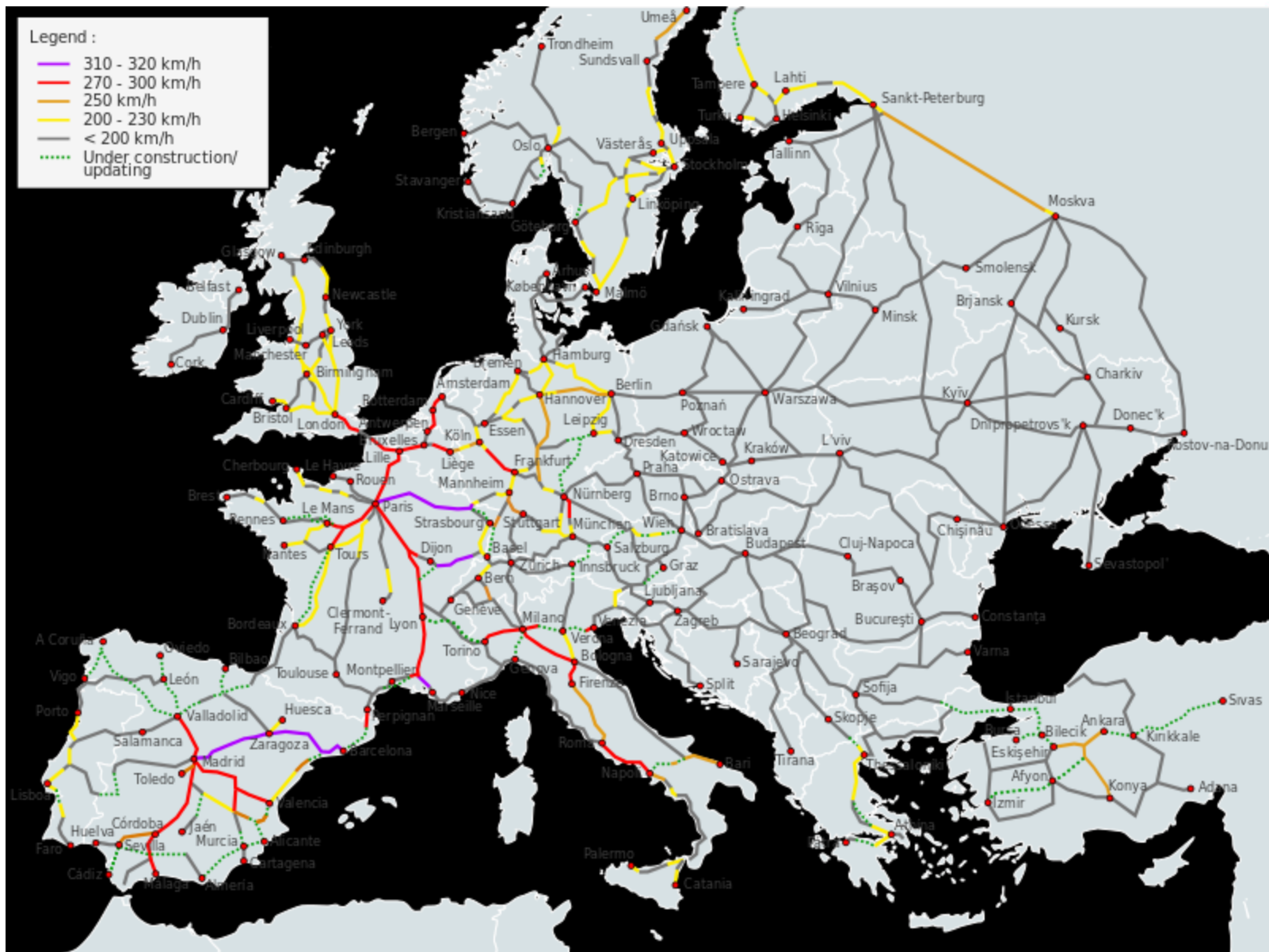
# Detailed Transport Network



# Danish Public Transit







# Togfonden

- 28.5 Billion Kroner (\$5 billion)
- High Speed Alignment
- European Signal Standard
- Resumption of Electrification
- Separately Funded
  - Femern Bælt-forbindelsen  
Femern Belt Link
  - “The Bird Flight Line”
  - 41 billion kroner (\$6.9 billion)

# New Signals

Første strækning  
Hovedstrækning  
Sekundær strækning  
Udelysre som lebane



- ERTMS Level 2
- Entirely Cab Signalled
- No Wayside Signals

# Electrification

- 25k v, 50Hz
- 15k v, 16.3Hz
- Sweden
- Germany

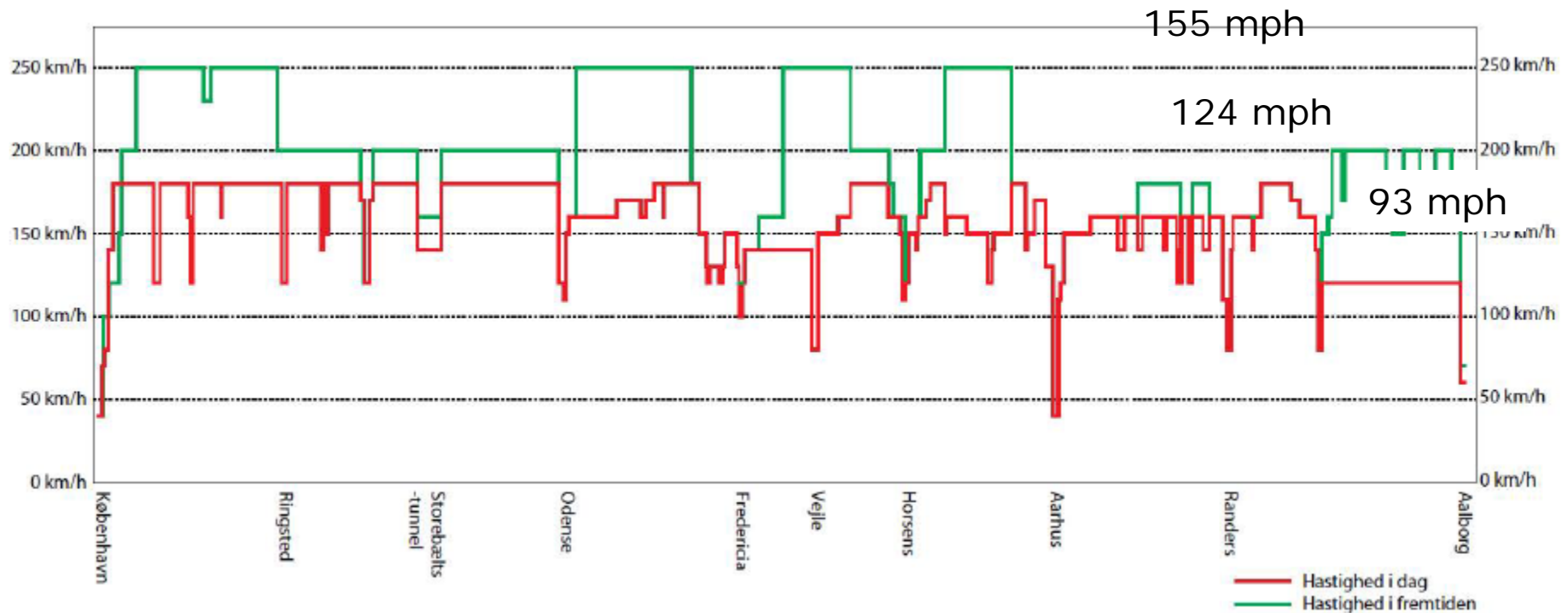


# Femern Bælt-Forbindelsen



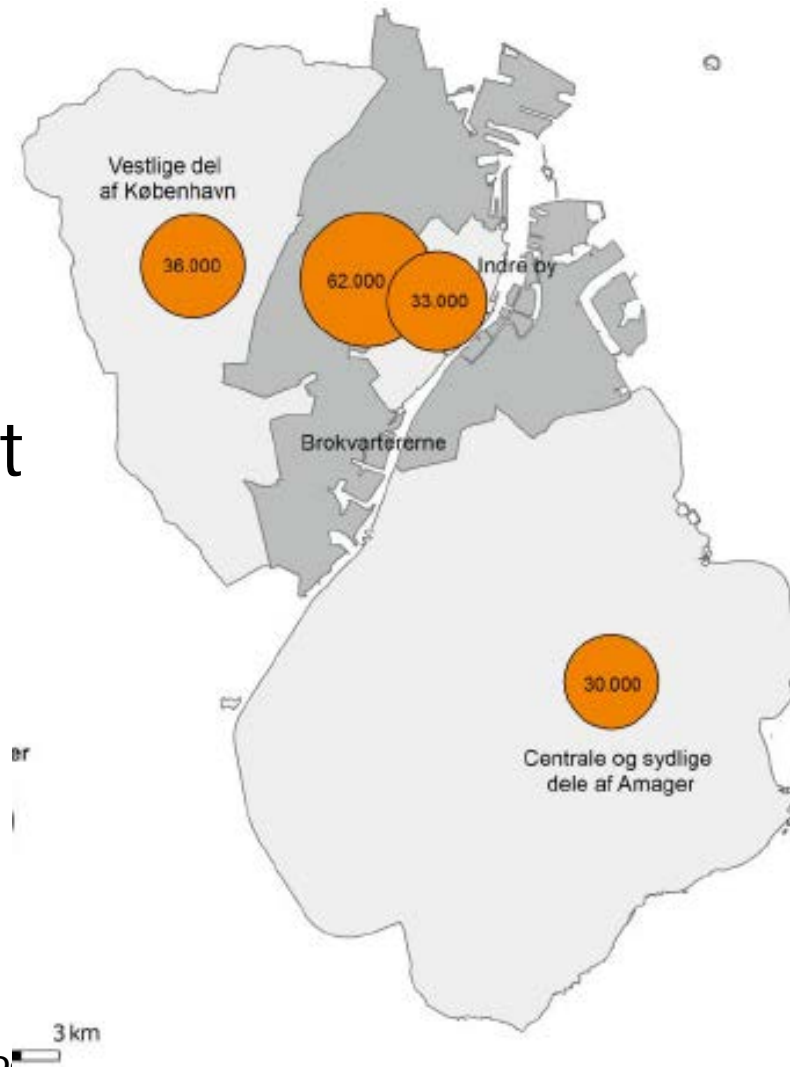


# Challenges Remain



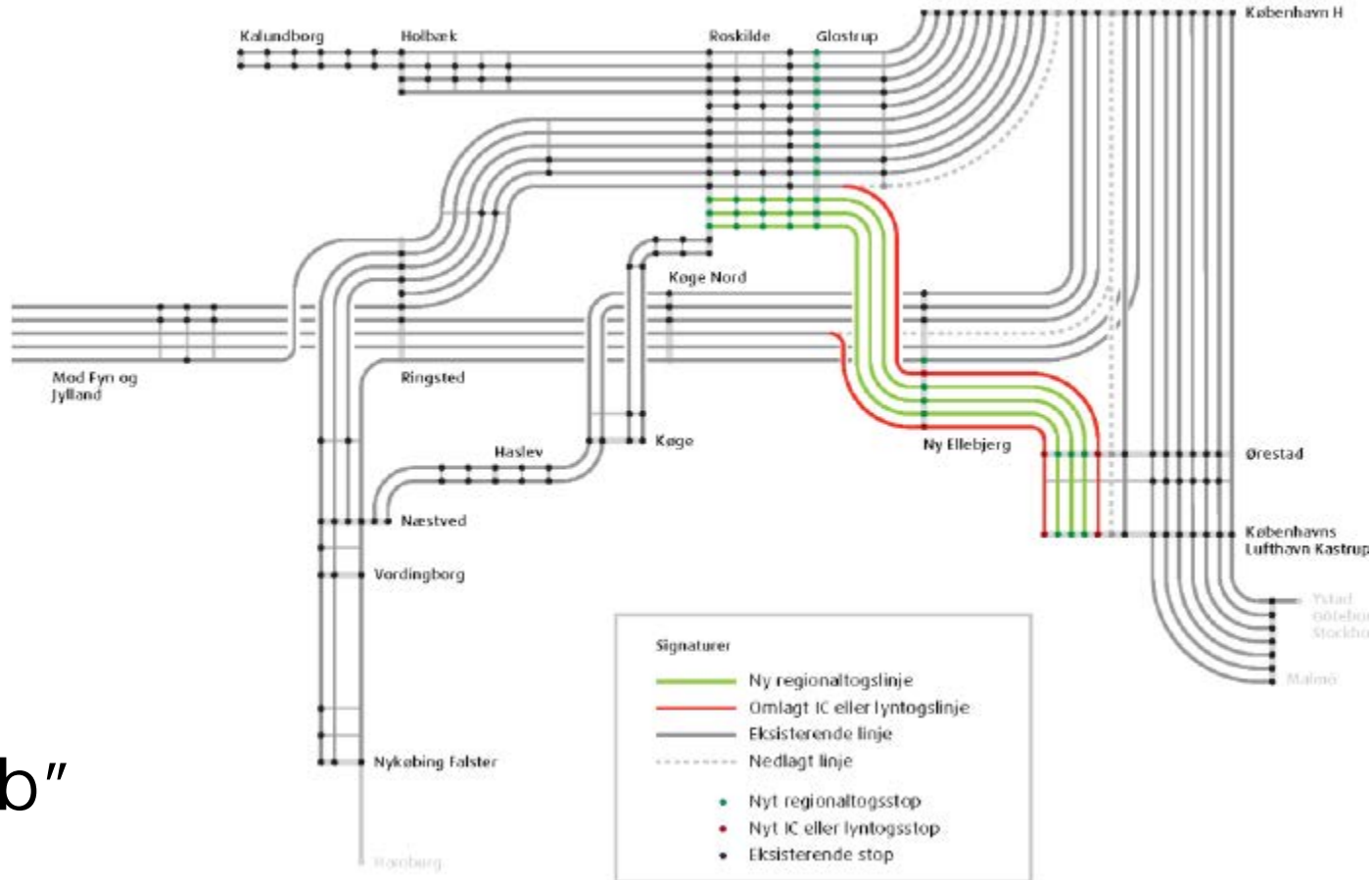
# Study at the Local Level

- Inner City is Only 30% of Destinations
- Yet Downtown Remains Transit Hub





## Solution: Bypass Downtown



**"1b"**



# Transport Model Analysis

- Robustness

Scenarie	Mange stop (1b)			Metro terræn (2a)			Letbaner (3)		
Station	Lufthavnen	Kongens Nytorv	Nørrebro Station	Lufthavnen	Kongens Nytorv	Nørrebro Station	Lufthavnen	Kongens Nytorv	Nørrebro Station
Køge Station	+3	+2	+1	+4	+4	+4	+0	+0	+0
Roskilde Station	+1	+6	+3	+4	+2	+2	+0	+0	+0
Frederikssund station	+2	+0	+0	+5	+3	+0	+0	+0	+1

# Project Performance

Scenario	1b Rail	2a Metro	3 Light Rail
Million hours per year time saved	1.8	3.42	3.1
Growth in million trips per year	0.5	2.77	1.98
Reduction in boardings at Central Station	13	8	7
Reduction in boardings at Nørreport	7	10	10
Project Cost, million kroner	DKK 950	DKK 10,180	DKK 15,180

# Summary

- Massive Investment in Rail
- Service Design Tested in National Transport Model
- Linking Scandinavia to Southern Europe
- Increasing Flow and Efficiency

# Thank You

